ENGINEERING TRIPOS PART IIA

Wednesday 7 May 2008 9 to 10.30

Module 3B3

SWITCH MODE ELECTRONICS

*Answer not more than **three** questions*

All questions carry the same number of marks

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments.

STATIONERY REQUIREMENTS

Single-sided script paper

SPECIAL REQUIREMENTS

Engineering Data Book

CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1 The single phase bridge rectifier shown in Fig. 1(a) is used to provide the dc supply in a 240V, 11 W compact fluorescent lamp. Give three reasons why this is a good choice. [15%]

The average current drawn by the load is found to be 44 mA . Carefully sketch the waveform of voltage appearing on the 2.2 μF smoothing capacitor under steady state operation, marking on your sketch periods over which the diodes conduct. Find the approximate diode conduction time and peak diode current, stating your assumptions. [50%]

The fluorescent tube is supplied by a resonant inverter as shown in Fig. 1(b). The inverter operates at 40 kHz and takes sine half cycles of current from the dc link. Estimate the high frequency ripple current in the smoothing capacitor, stating any assumptions. [25%]

Give two reasons why the high frequency ripple current in the smoothing capacitor should be minimised. [10%]

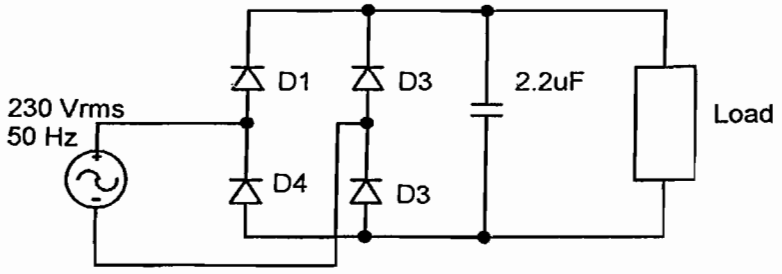

Fig. 1(a)

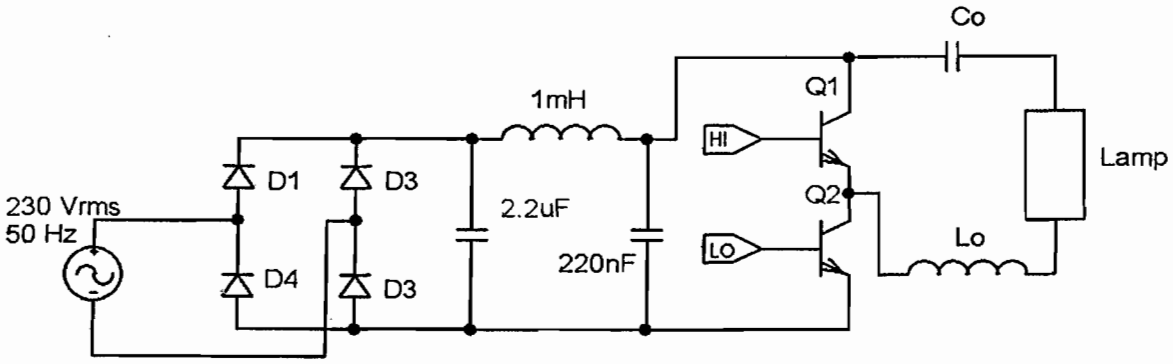

Fig. 1(b)

2 (a) For one leg of the IGBT inverter shown in Fig. 2, explain carefully how the individual switches should be controlled to make the output voltage independent of the power factor of the load. Describe briefly the factors which influence the choice of *deadtime*. [25%]

(b) Making reference to a sketch of the output voltage spectrum, give one advantage and one disadvantage of a high switching frequency in an inverter employing *sinusoidal pulse width modulation.* [15%]

(c) On a sketch of three-phase voltage waveforms (either phase voltage or line voltage), identify the six sectors associated with *Space Vector Modulation* (SVM) when applied to a three phase IGBT inverter, as shown in Fig. 2. Hence explain the meaning of the term SVM. [25%]

Using SVM with a switching frequency much greater than the sinewave output frequency, write down a sequence of states for two cycles of switching allowing for a reduced magnitude in the three phase output voltages. By examination of the three phase waveforms or otherwise find the duty ratios required for the adjacent vectors to give a depth of modulation of 50% at an angle of 15^{o} from the start of a sector (any sector will do).

How might your switching pattern be changed to account for the power factor of the load? [35%]

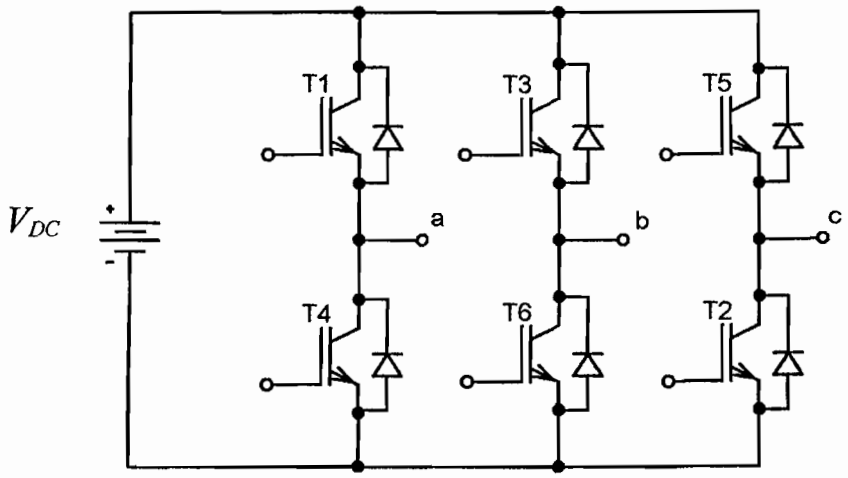

Fig. 2

(TURN OVER

3 (a) A 50 W *step up converter* to be used for a solar car electrical system is shown in Fig. 3(a). The solar panel supplies an open circuit voltage of approximately 22 V under full sunlight. The output of the converter is connected to a large battery with a substantially constant voltage of 200 V .

Sketch waveforms of the drain-source voltage and the drain current for the MOSFET at turn off, paying attention to the detailed operation. Explain carefully the choice of MOSFET for this application and comment on the assumption of high efficiency. Hence or otherwise, suggest a suitable switching frequency for this application and an approximate value for the gate resistance for the MOSFET, for which the input capacitance is 450 pF , stating your assumptions. [50%]

(b) For the system of Part (a), derive an expression for the duty ratio of the MOSFET in terms of the voltage supplied to the input of the converter V_{pv} and the battery voltage, assuming continuous current in the inductor and ideal components. [20%]

The Solar panel response to sunlight is shown in Fig. 3(b). The step up converter is used with a feedback controller to obtain maximum power from the solar cell by operating at the *Maximum Power Points* (MPP) under various light conditions. *Continuous current mode* is chosen for the converter. Estimate the duty ratio required for

(i) the maximum output overall and

(ii) at a reduced incident light level of 200 Wm^{-2} .

Hence propose a value for the minimum inductor size required under both conditions, assuming ideal components in the converter and an ideal battery load. [30%]

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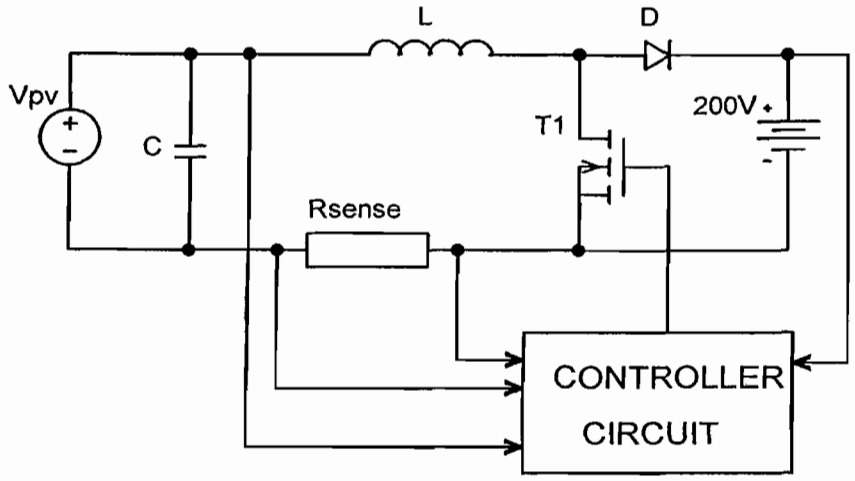

Fig. 3(a)

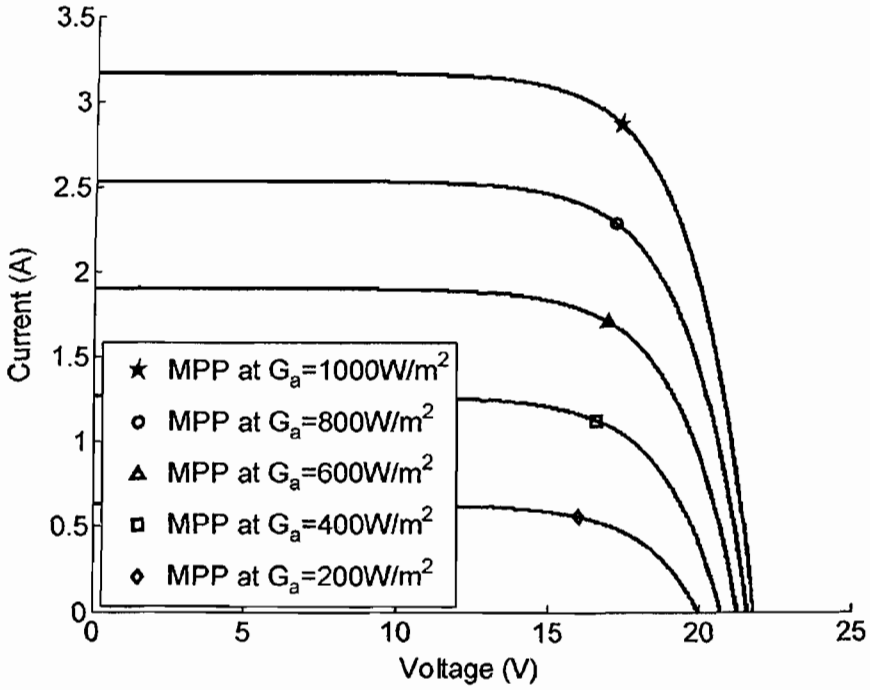

Fig. 3(b)

(TURN OVER)

4 (a) Give two reasons for the choice of a bipolar transistor for the main switching device in a 40 W power supply for mains powered computer speakers. Explain briefly the necessity of ensuring that the base drive current is appropriate. [25%]

(b) A *resonant discontinuous forward converter* circuit is proposed, as shown in Fig. 4(a). The controller circuit sets the peak current in the transistor using the current sense resistor and ensures that the transistor is off for sufficient time for the transformer core to be reset.

The specified transformer design has a turns ratio of 120:9 , magnetising inductance referred to the primary of 17 mH and a total leakage inductance referred to the primary of 150 μH in the arrangement shown in Fig. 4(b). For a constant output voltage of 9 V with the voltage across C_{in} at 136 V , sketch the transistor collector current when operating with a duty ratio of 0.5 at 40 W load. You may ignore losses and assume an ideal diode D_f. Mark on your sketch the value of the peak current. [25%]

When the transistor turns off, capacitor C_s acts to control the transistor voltage in a resonant manner. Show that there are two periods to the voltage waveform, one associated with the leakage inductance and one dominated by the magnetising inductance. Explain carefully the behaviour during the first (rapid) voltage rise and estimate a value for the final voltage in this period.

Hence or otherwise find the peak voltage appearing on the transistor. [35%]

Give three reasons why the proposed circuit is likely to be very efficient. [15%]

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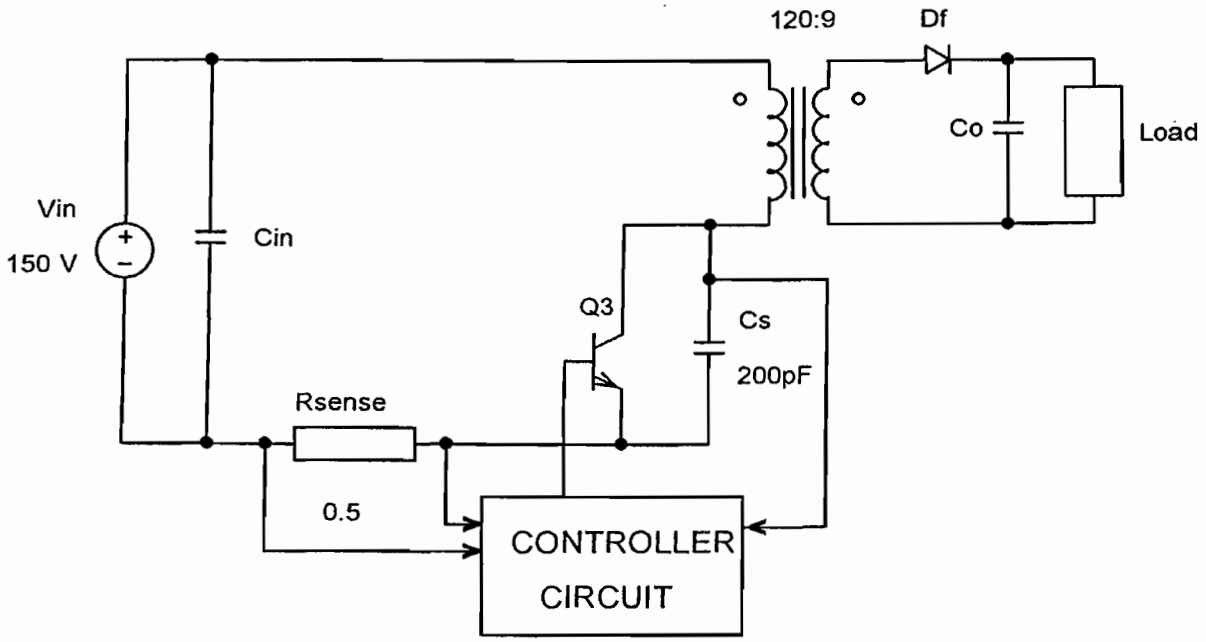

Fig. 4(a)

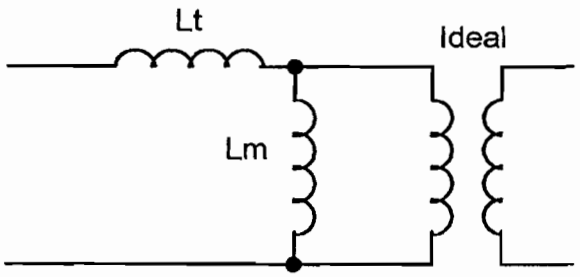

Fig. 4(b)

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